GRAVITATIONAL BIOLOGY
AND FUTURE PROSPECTS - PART II

EFFECT OF ALTERED GRAVITY ON BIOLOGICAL SYSTEMS

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Effects of a Change in Gravity on Biological Systems

The origin and subsequent evolution of life on Earth have taken place in an omnipresent environment of 1g. On Earth, living organisms exhibit a number of tropism phenomena depending upon their responses to various physical parameters such as wind, gravity, light, touch, etc. Gravitropism is the phenomenon of movement in response to gravity. Some organisms have learned to take advantage of the force of gravity by using it as a reference for orientation. Trees have adapted themselves to grow to extraordinary heights; a giraffe, with his head so far above his heart, needed considerable pressure to send blood to its brain.

Unicellular organisms: are single-celled organisms such as bacteria, amoebas, and plankton, including flagellates, ciliates, etc. The directional response of unicellular organisms with respect to the gravitational field of the Earth is called the gravitaxis. Some species also show a gravity-related active regulation of swimming rate called gravikinesis, which is responsible for increased or decreased swimming rates during upward and downward swimming, respectively. The whole cell body of Paramecium and flagellate Euglena gracilis works as a statolith because they don't have any special organelles for gravitation. It develops pressure on the lower membrane to activate mechanosensitive ion channels. Physarum is a single-celled, multinucleated organism that has a very strange location in the interphase nuclei that seems to have something to do with detecting gravity. Before, it was believed that the microgravity environment couldn't affect bacteria because of their small size. However, the majority of space flight studies have reported many changes in bacterial growth and behaviour. There has been evidence that a change in gravity can affect any or all of the three phases of microbial growth (lag, exponential, and stationary).

Sea animals live at the bottom of the sea at a depth of about 20,000 feet under high external pressure. These kinds of adaptations to gravity inspired scientists to study gravity perception mechanisms in various living organisms. Let us understand the multiple effects of gravity on biological systems.

Multicellular organisms: In contrast to unicellular organisms, multicellular organisms are more complex in their structure and function. They sense gravity and use this sensory information to generate coherent locomotor and other related responses. As species on land increase in size, they require more and more support structures appropriate for the loads imposed. Crawling species may have more complex mechanisms for balance or gravity sensing, fluid regulation, and locomotion as they alternate between horizontal and vertical positions. Some species, such as aquatic insects, detect gravity using air bubbles trapped in certain passageways, viz., tracheal tubes. Snakes with a wide range of body sizes occupy many different environments and display wide variations in their behaviour. They have a wonderfully designed cardiovascular system, which enables them to circulate blood against the force of gravity.

In plants, statoliths (also called amyloplasts) within the statocyte provide information about the direction of the g-vector. In the past, Aristotle and Charles Darwin were the first to recognize a gravity-perceptive system in plants. According to their theory, the site of photoperception is located in the coleoptile tip, and the site of graviperception is in the root cap.

NASA astronauts Jessica Watkins and Bob Hines work on XROOTS, which used the station's Veggie facility to test liquid-and air-based techniques to grow plants rather than traditional growth media.

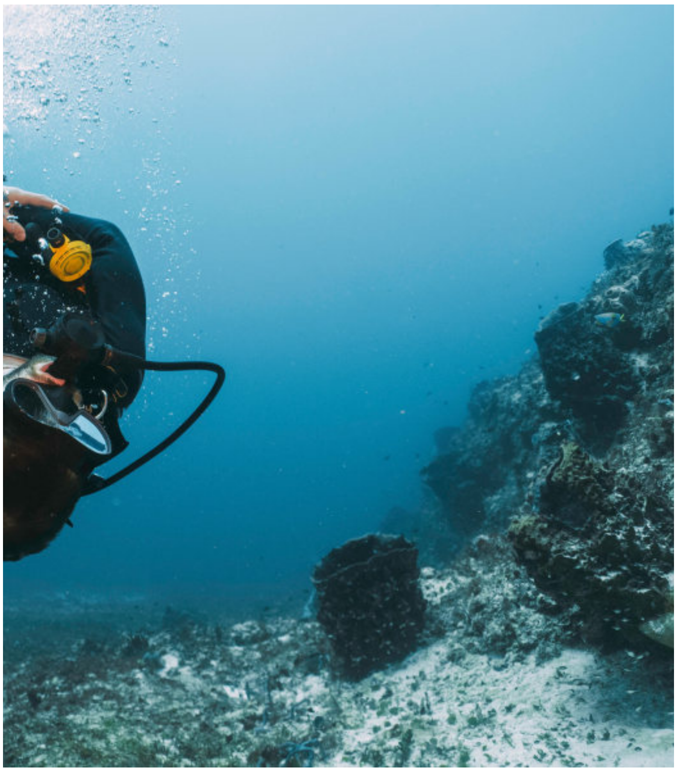
A researcher at Johnson Space Center performs DNA and RNA sequencing on microbes as part of the Biomolecule Extraction and Sequencing Technology (BEST) experiment. The same sequencing procedure was performed in orbit aboard the International Space Station, and the results were compared to those on the ground. This capability provides better insight into the effects of the spaceflight environment on microbial life.
Credits: NASA

Statoliths, which are dense organelles, interact with other cytoplasmic structures in statocytes, which are cells that sense gravity. A variety of environmental factors, such as light temperature, gravity, water, humidity, etc., influence the growth and development of plants. Of all these factors, gravity being a constant, plants have used this reliable factor to guide their growth, morphology, and development. The growth rate of wheat coleoptiles and garden cress hypocotyls sped up when grown in space. There were also changes in the shape and differentiation of cells, as well as the distribution and structures of plastids. Hypergravity stimuli give plants a higher g force that changes their shape and stops seeds from germinating and growing. They also stop the growth of radish and cucumber hypocotyls, cress hypocotyls, azuki bean epicotyls, and Arabidopsis hypocotyls. Microgravity, whether real or simulated, slows down photosynthesis in higher plants by changing the photosynthetic apparatus, such as by lowering the activities of photosynthetic pigments or PSI or PSII photosystems. However, few studies indicate an increase in photosynthetic capability in plants under simulated microgravity.

Various multicellular organisms studied under spaceflight include rats, mice, non-human primates, fish, invertebrates, amphibians, insects, and humans. In these organisms, widely studied systems included:

- The neurovestibular system.
- The musculoskeletal system.
- The immune system.
- The neurological system.
- The cardiovascular system.
- The reproductive system.

Both chronic microgravity exposure and long-duration bed rest induce cardiac atrophy in humans, which leads to reduced standing stroke volume and orthostatic intolerance. Immunological functions are significantly depressed in astronauts as a consequence of the stress of space flight. Space flight also alters leukocyte distribution, interferon, and other cytokine production. A long-duration spaceflight mission has a significant effect on leukocyte count, a decrease in T cell count, and decreased mitogen-induced interleukin-2 (IL-2) production. Microgravity is also known to produce a number of neurological disturbances during space flight. The associated space motion sickness is among the earliest signs of adaptation to this new environment. Other disorders include space adaptation syndrome, postural illusions, postural imbalance, visual disturbances, neuromuscular weakness, and fatigue.



Microbial Observatory-1 aboard the ISS NASA ID: iss043e198394

These effects of altered gravity on living organisms are of great interest to the scientific and academic fraternity, which not only addresses the fundamental biological processes that are affected by gravity but also addresses various challenges and develops strategies for ensuring safe long-duration space travel for astronauts.

In next issue let's understand Ongoing Exploration in Gravitational Space Biology

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